Transoral Approach and Extended Modifications for Lesions of the Ventral Foramen Magnum and Craniovertebral Junction

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Abstract

Objectives: To describe our method of performing the transoral approach and the extended approaches to the ventral foramen magnum and craniovertebral junction and review the technical aspects and operative nuances.

Design: Review

Results: The transoral approach provides direct midline exposure to access extradural disease located at the craniovertebral junction and ventral foramen magnum. The corridor of exposure is generally limited by the extent to which the patient can open his or her mouth. The location of the hard palate relative to the craniovertebral junction limits superior exposure, whereas the mandible and base of the tongue limit the inferior exposure. In most cases, exposure can be obtained from the inferior clivus to the middle to lower C2 vertebral body. Extended transoral approaches can be performed to increase exposure if necessary. These approaches include transmaxillary (Le Fort I maxillotomy), transmaxillary with a midline palatal split (extended "open-door" maxillotomy), transpalatal, and median labiomandibular glossotomy (transmandibular split).

Conclusions: The transoral approach is effective in providing direct access to extradural midline lesions of the craniovertebral junction. Using a specialized retractor system, the inferior clivus to the C2 body can be exposed. Lesions that extend beyond these limits can be accessed with extended approaches as described.

Key Words: Craniovertebral junction; Foramen magnum; Skull base surgery; Transoral approach

Running Title: Transoral Approach and Extended Approaches

Abbreviations: MRI, magnetic resonance imaging

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Introduction

Lesions of the ventral foramen magnum and craniovertebral junction present a difficult challenge. This complex region can harbor neoplastic, degenerative, or inflammatory lesions that can cause compression of the cervicomedullary junction and craniocervical instability. Treatment may require surgical decompression and subsequent craniocervical stabilization. Various midline anterior approaches have been developed to access lesions of the central cranial base and craniovertebral junction, including the transbasal, transnasal transsphenoidal, Le Fort I transmaxillary, transfacial, extended maxillotomy, transpalatal, transmandibular, and transoral approaches.[1-10] Each approach has its own advantages, disadvantages, and limitations of exposure. Surgeons should be familiar with the various midline anterior approaches and their modifications in order to select the most appropriate approach for the given lesion.

The location and extent of the lesion are the major determinants influencing selection of the appropriate cranial base approach. The transoral approach provides direct midline access to the craniovertebral junction that is most suitable for extradural lesions, such as chordomas, chondrosarcomas, giant cell tumors, and rheumatoid or degenerative pannus.[6,11-15] This approach is best suited for strictly midline extradural lesions that occupy or are behind the inferior clivus down to the C2 vertebral body. Extensive lesions involving the sphenoid sinus and upper and middle clivus may require the more superior exposure offered by the transpalatal, transmaxillary (Le Fort I maxillotomy), or transmaxillary with a mid-palatal split (extended “open-door” maxillotomy) approaches.[5,8,16-20] If the lesion extends more inferiorly from C2 to C4, additional inferior exposure can be gained with a median labiomandibular glossotomy or a mandibular

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swing–transcervical approach.[7,21-25] This article focuses on the technical aspects of the transoral approach for accessing lesions of the ventral foramen magnum and craniovertebral junction. The transmaxillary, transpalatal, and transmandibular extensions are also reviewed.

Historical Overview

Lesions of the craniovertebral junction have historically been challenging to remove surgically because of the difficulty in obtaining adequate exposure with minimal morbidity to the neural structures. Initial attempts at enlarging the foramen magnum were performed with posterior and posterolateral decompressive approaches, but the results were unsatisfactory.[26] Because of the limited exposure and increased risk of cerebrospinal fluid leakage and subsequent infection, the transoral approach was rarely used and, prior to the 1960s, was reserved primarily for accessing retropharyngeal abscesses. Beginning in 1962, the transoral approach was used to treat tuberculous lesions of the craniovertebral junction.[27] Despite this, criticism of transoral surgery continued because of its limited exposure, poor illumination, and lack of proper instrumentation.[8] The advent of the operating microscope, microsurgical instrumentation, and specially designed transoral retraction systems contributed to the re-popularization of the transoral approach. Currently, the transoral approach is used mostly for basilar invagination, compressive rheumatoid pannus, and extradural craniovertebral junction tumors. Previously described techniques of craniofacial osteotomies have been rediscovered and incorporated into modern cranial base surgery for increasing exposure of the transoral approach to access more extensive lesions.[4,5,9,10,17,19,28] More recently, direct endoscopic

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approaches to the lower clivus and odontoid process have been described using an expanded endonasal endoscopic approach[29,30] as well as an endoscopic transcervical approach.[31]

Surgical Considerations

The standard transoral approach primarily provides midline exposure of the inferior one third of the clivus, the anterior craniovertebral junction, and the C1-C2 complex. Its main advantage is that it provides a direct extradural approach that does not require any brain retraction. This midline trajectory also accesses the lower pons, the medulla, the cervicomedullary junction, and the vertebrobasilar artery complex intradurally; however, we generally do not choose this approach for intradural lesions because it traverses a "contaminated" operative field, which is one of the main disadvantages of this approach. A watertight dural closure is difficult to achieve using a transoral approach, and a subsequent cerebrospinal fluid leak may result in life-threatening bacterial meningitis. The lateral limits of this exposure are defined by the mandible and the tonsillar pillars. The superior and inferior limits are usually the lower clivus and the middle to lower C2 vertebral body, respectively, although this will vary with each individual. If there is basilar invagination, exposure further down the spinal column becomes possible. Restricted jaw opening such as that which may occur in patients with rheumatoid arthritis may reduce the extent of exposure, especially inferiorly.

Radiographic images, including enhanced magnetic resonance imaging (MRI) and fine-cut 3D-reconstructed computed tomographic scans of the craniovertebral junction

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should be carefully reviewed before selection of the appropriate approach. It is important to determine initially whether the lesion is suitable for a midline cranial base approach and whether the lesion is situated intradurally or extradurally. A transoral approach should be considered if the lesion is situated in the midline extradurally. If it extends more laterally or appears to be located intradurally, alternative approaches such as the far lateral or extreme lateral transcondylar approaches should be considered. To obtain adequate line of sight in the superior and inferior trajectories, the opening of the mouth should be at least 2.5 to 3 cm between the upper and lower teeth. The superior extent of the exposure can be estimated preoperatively by drawing an imaginary line in the plane of the hard palate towards the craniovertebral junction on a sagittal MRI. If the lesion is midline and is situated above this line, an extended transsphenoidal approach may be suitable. If, however, the lesion is situated below the plane of the hard palate, a transoral approach alone may be sufficient. Alternatively, a Le Fort I maxillotomy with or without a palatal split may be considered if the lesion extends above and below the plane of the hard palate. If the lesion extends inferiorly beyond the line of sight of a standard transoral (roughly beyond the lower body of C2 to the C2/3 disk space in most cases), a labiomandibular median glossotomy (transmandibular split) approach may be appropriate to gain more inferior exposure. Although these extended approaches provide increased exposure for more extensive lesions, these procedures increase morbidity and should be used judiciously.

Preoperatively, we obtain dynamic plain cervical radiographs in flexion and extension views to evaluate for pre-existing instability at the craniovertebral junction. In some cases, the expansion of the tumor has destabilized the occipitoatlantal or

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atlantoaxial joints, thus requiring a subsequent or prior stabilization procedure. Even if no instability is present, however, most cases will require stabilization after resection of the lesion and the involved ligaments because of postoperative iatrogenic instability. Either occipitocervical or atlantoaxial stabilization can be performed, depending on the level of instability. We generally obtain a high-resolution stereotactic computed tomography scans of the craniovertebral junction for preoperative planning.

If severe deformity or cranial settling is detected preoperatively, reduction is attempted with cervical traction using Gardner-Wells tongs. In cancer patients with metastatic disease who do not have neural compression, a posterior occipitocervical stabilization to treat the instability may be appropriate palliative treatment given the patients' short life expectancy. If, however, there are compressive pathological conditions, if the lesion is a primary neoplasm, or if the patient's neck cannot be reduced to an anatomic position sufficient to decompress the neural elements, a transoral resection followed by a posterior stabilization is an effective strategy.

Surgical technique: transoral approach

Positioning and Application of Transoral Retractor System

The patient is placed in the supine position with the head resting on a doughnut pad. The neck is slightly extended to facilitate a direct line of sight to the craniovertebral junction. Cervical traction is applied if it was implemented preoperatively for reduction. The patient is orally intubated. Awake fiberoptic intubation may be considered in patients who have marked spinal instability. Topical corticosteroid cream may be applied to the

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tongue to minimize postoperative tongue swelling. We do not use three-point skull fixation because the head is adequately secured once the transoral retractor system is set.

We apply the Spetzler-Sonntag transoral retractor system (available from Jarit Surgical Instrument division, Integra LifeSciences Corporation, Hawthorne, NY), which is rigidly attached to the operating table to prevent the retractors from moving intraoperatively and to stabilize the patient's head (Figs. 1–3).[32] Proper positioning of the transoral retractor maximizes exposure and obviates the need to incise the soft palate or uvula to gain the needed exposure. The patient's tongue is retracted inferiorly by a wide and rigid retractor blade. The endotracheal tube can be placed under the tongue retractor, but we prefer to route it along the side of the mouth to reduce tongue compression. It exits the corner of the patient's mouth and does not obstruct the surgical exposure. This provides adequate exposure and eliminates the need for a preoperative tracheostomy in most cases. We usually reserve a tracheostomy for those patients who have pre-existing bulbar or respiratory dysfunction or those who are undergoing a median labiomandibular glossotomy approach. Exposure of the cephalad posterior pharynx can be maximized by elevating the soft palate and uvula superiorly with a small retractor blade that attaches to the transoral retractor. This avoids injury to or incision of the soft palate, which can be difficult to repair and can result in dysphagia, dysphonia, and nasal regurgitation of fluids. Teeth guards, which are attached to the retractor frame, are placed around the upper teeth for protection. Adjustable lateral retractors attached to the retractor frame are used to retract the pharyngeal soft tissues laterally. After the retractor system is in place, the tongue is carefully inspected to confirm that it is free from compression between the retractor blade and the teeth. Failure to recognize this compression can result in necrosis

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or swelling of the tongue. After final positioning of the retractors, the mouth, oropharynx, and retractors are prepped with Betadine solution. The surgeon operates from the head of the patient, using an operating microscope to enhance magnification and illumination. Prophylactic antibiotics are administered intraoperatively. We do not perform preoperative bacterial cultures of the oropharynx.

Incision and Muscle Dissection

The posterior pharyngeal wall can be infiltrated with 0.5% lidocaine with 1:200,000 epinephrine solution, but this step is usually not necessary for hemostasis if the monopolar cautery is used to open the pharynx as described below. The midline is located by palpating the tubercle of C1; however, this anatomic landmark may be absent or distorted in patients who harbor tumors in this location. Using a fine-tip, shielded monopolar cautery (Colorado MicroDisection Needle, Stryker Leibinger, Portage, MI) set at low cutting power, the posterior pharyngeal wall is incised longitudinally in the midline over the region that is to be resected (Fig. 2B). The incision is progressively carried through the mucosa, the midline raphe between the pharyngeal muscles, and the anterior longitudinal ligament down to the bone using a regular monopolar cautery tip. The lateral retractors help in exposing the tissues as the incision is deepened. The tip of a regular monopolar cautery, bent to a near-right angle, is then used in a sweeping motion to detach the ligaments from the bone in a subperiosteal fashion. This technique greatly reduces bleeding from these well-vascularized tissues. The longus colli and the longus capitis muscles are mobilized laterally and held in place with tooth-bladed lateral

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pharyngeal retractors to expose the inferior clivus, C1 arch, and C2 vertebral body (Fig. 4).

Removal of C1 Arch and Odontoidectomy

The following section is a description of the removal of the arch of C1 and odontoid process in the absence of a tumor. The purpose of this description is to illustrate the anatomy of an intact craniovertebral junction that has not been destroyed by a neoplastic process. All soft tissues are cleared with electrocautery before removal of the anterior C1 arch and the odontoid process. Using a high-speed drill, bone cuts are made through the arch of C1 on both sides of the odontoid process (Fig. 4). Rongeurs are used to remove the arch of C1 to expose the underlying odontoid process. Before the odontoidectomy is performed, the edges of the odontoid process should be clearly defined and freed from any ligamentous attachments. The apical and alar ligaments are detached from the odontoid using sharp curettes. A right-angled curette is used to free the posterior cortex of the odontoid from the underlying soft tissues and ligaments. The center of the odontoid process is hollowed out using a high-speed drill and copious irrigation and suction, leaving an eggshell-thin layer of outer cortical bone. The remaining eggshell-thin bone is removed with either the drill or Kerrison rongeurs. By systematically detaching the odontoid from its associated ligaments before removing the odontoid, the surgeon can prevent upward retraction of the odontoid tip towards the clivus should the base of the odontoid be prematurely transected.

After removal of the anterior arch of C1 and the odontoid process, the transverse ligament can be identified. Removal of the transverse ligament, tectorial membrane, and

any residual ligaments may be necessary to remove pannus. The compressive pathology should be resected to decompress the underlying craniovertebral junction dura mater adequately. If necessary, the inferior clivus can also be removed with a high-speed drill and rongeurs.

Tumor Removal

In some cases, tumor may be encountered on opening the posterior pharyngeal mucosa and the anatomy of the craniovertebral junction may be distorted by the tumor. Ringed curettes, rongeurs, bipolar cautery, and suction are used to remove tumor in a piecemeal fashion. If tumor has involved the ligaments, they can be removed with rongeurs. If the odontoid process is intact but will be resected to gain deeper access, the apical and alar ligaments should be detached to prevent upward retraction of the odontoid tip. The plane between the tumor and dura mater should be identified to facilitate tumor removal.

Tumor that extends longitudinally into the clivus or the body of C2 is well visualized by this approach and can typically be removed using curettes and a high-speed drill until normal cancellous bone is identified. Tumor that has extended further laterally is more difficult to visualize and to remove. Tumor in these regions can be removed using angled curettes, pituitary rongeurs, and suction, while being careful not to injure the vertebral artery. A side-angle view endoscope may help with lateral visualization as well. If the tumor has eroded the occipitoatlantal joints, the patient should undergo a posterior stabilization either before or after tumor removal, as should any patient in whom the arch of C1 or the odontoid is disrupted by the surgery. If the occipital condyle

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is drilled out because of tumor involvement, the surgeon should be mindful of avoiding injury to the hypoglossal nerves, which traverse this structure in the hypoglossal canal located in the anterior 1/3 of the condyle.

Tumor may be adherent or may have infiltrated the dura mater. If the dura mater has been violated by tumor, care should be taken not to injure the intradural structures, such as the basilar artery, perforators, and brainstem. If there is an intraoperative cerebrospinal fluid leak the dura mater is reconstructed with autologous or allograft fascia lata, fat, and fibrin glue in several layers. This is followed by temporary lumbar drainage, which should be performed promptly at the end of the procedure. If, however, the dura mater is intact, the extent of decompression can be evaluated intraoperatively by injecting contrast into the epidural space and viewing this fluoroscopically.

Closure

Performing an adequate closure in a deep wound after a transoral operation can be challenging. It can be facilitated using long, thin needle holders with a curved tip and instrument-tying techniques (similar to those used in microvascular anastomosis). If the dura mater is intact, the wound closure proceeds in two layers (Fig. 5). First, the muscle layer is approximated in a horizontal mattress with 3-0 Vicryl sutures. We use ½-circle Lane cleft palate needles because they are small and stiff enough to resist bending forces. These benefits outweigh the inconvenience of not having a swedged-on needle. The mucosal layer is then approximated with simple interrupted 3-0 Vicryl sutures using the same needle. Care should be taken not to pull the sutures too tight because this can strangulate the delicate mucosal tissues. In cases in which the dura mater is intact,

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prophylactic antibiotics are continued for 24 hours. We have not had any complications of wound dehiscence from the described two-layer wound closure. Reapproximation of the deeper pharyngeal muscle layer provides added strength to the closure. The mucosal layer incision heals quite rapidly. If, however, wound dehiscence is encountered, an aggressive washout and reclosure of the wound should be performed and broad-spectrum antibiotic medications should be administered.

If the dura mater has been violated, either by the tumor or by the surgical approach, reconstruction of the cranial base followed by temporary lumbar drainage is paramount in preventing a cerebrospinal fluid leak. Because primary closure of the dura mater is usually not feasible, autologous fascia lata and fat are harvested from the thigh. Alternatively, allograft fascia lata supplemented with fat harvested from the abdominal wall or other suitable site has been used successfully. The dural defect is reconstructed by grafting a piece of fascia lata in an on-lay fashion followed by fibrin glue, fat, Surgicel, and additional fibrin glue (Fig. 5). The placement of excessive fat may result in neural compression and should be avoided. Broad-spectrum antibiotic coverage is extended for about 5 days. The closure of the pharyngeal muscles and mucosa proceeds as described above.

Posterior Stabilization

We prefer to perform a posterior stabilization immediately after the transoral resection (Fig. 6). This allows restoration of normal alignment that often is disrupted by the pathologic process as well as stabilization. If the patient is in good alignment initially however, the option exists to perform this step before the transoral approach. In almost

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all cases, the craniovertebral junction will be rendered unstable by the extent of pathologic destruction produced by the lesion, ligamentous weakening, and/or operative bone removal.[33,34] The key stabilizing structures in the atlantoaxial region are the odontoid process of C2 held within the anterior ring of C1 by the very strong transverse ligament. Resection of the anterior arch of C1 or a transoral odontoidectomy disrupts this complex and renders the spine very unstable because it allows a significant increase in the amount of translational and rotational motion.[35] If basilar invagination was present preoperatively, an occipitocervical stabilization is usually required.[32] We rarely place anterior bone grafts into the transoral defect because they do not restore spinal instability and are difficult to fixate. They also become dislodged easily and are associated with a high rate of infection.[32]

The patient is carefully repositioned in the prone position with the head placed in three-point fixation for a posterior stabilization. We use a cervical collar to augment the stability while carefully turning the patient. The craniovertebral junction is placed in anatomic alignment under fluoroscopic visualization for subsequent stabilization. The motion segments that require stabilization are definitively determined at the time of surgery because in the face of atlantoaxial instability it is difficult to determine whether there is atlanto-occipital instability. After the spine is exposed, a towel clamp or Kocher clamp is placed on the posterior arch of C1, and force is carefully applied under fluoroscopic visualization. If C1 translates in the anteroposterior plane by more than 1 mm, the occipitoatlantal joint is unstable and the fusion construct is taken up to the occiput to perform an occipitocervical fusion. If, however, there is no translation of C1 relative to the occiput, only C1-2 stabilization is usually needed. This may be done with

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transarticular screws or a direct C1 lateral mass screw and C2 pars screw construct (Harms technique). If C1 and C2 cannot be fixated directly then the construct may need to be extended to achieve an instrumented occipitocervical stabilization, but in most cases the versatility of modern instrumentation systems allows a short segment fusion to be accomplished.

Postoperative Care

In most cases, we attempt routine extubation immediately after surgery unless we are concerned about a difficult airway. As described earlier, topical corticosteroids applied to the tongue minimize postoperative swelling. We generally do not place a nasogastric feeding tube postoperatively, because it may cause irritation to the pharyngeal wound closure. Oral feedings are withheld for 24 to 48 hours; however, the patient is given oral swabs to moisten the mouth and may suck on ice chips. After 24 to 48 hours, the patient is started on clear fluids and later advanced to a mechanical soft diet as tolerated.

Extended Transoral Approaches

Lesions that extend beyond the exposure limits of a standard transoral approach may require an extended transoral approach (Figs. 7–10). The need for an extended approach can be determined preoperatively on radiographic images, as described earlier. Extended approaches involve additional incisions and facial osteotomies to mobilize structures that may be obstructing the surgeon's line of sight to the lesion. A detailed anatomic knowledge of the craniofacial bones, soft tissues, and blood supply is critical in

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executing these approaches. The assistance of an experienced craniomaxillofacial surgeon may be helpful. Accurate reconstruction of the maxillofacial osteotomies is paramount to achieving excellent cosmesis and avoiding malocclusion. The options for gaining more superior exposure of the upper and middle clivus and sphenoid sinus are the transmaxillary (Le Fort I maxillotomy) approach, transmaxillary palatal split (extended "open door" maxillotomy) approach, or the transpalatal approach. To gain more inferior exposure from C2 to C4, a median labiomandibular glossotomy (transmandibular split) can be applied.

Transmaxillary Approach (Le Fort I Maxillotomy)

The transmaxillary approach involves a Le Fort I maxillotomy through a sublabial incision that allows inferior mobilization of the maxilla and hard palate, much like a trap door.[5,17,18,36] Thus, it has often been referred to as a "drop-down" maxillotomy approach. This maneuver provides more upward viewing to the sphenoid sinus and upper and middle clivus and also provides a wider panoramic exposure of the posterior naso-oropharynx. Inferior displacement of the hard palate, however, obstructs inferior viewing of the inferior portions of the body of C2, which is the major limitation of this approach. The lateral limits of exposure are the carotid arteries. This approach is appropriate for midline extradural lesions that are wider and involve the sphenoid sinus, clivus, and odontoid process. The Le Fort I maxillotomy has advantages over the extended transsphenoidal approach in that it provides wider exposure as well as more inferior viewing past the plane of the hard palate. In summary, the Le Fort I maxillotomy

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approach is indicated for extensive lesions that are too wide and too inferior for an extended transsphenoidal approach and too cephalad for a standard transoral approach.[33]

A sublabial incision is made along the upper alveolar margin extending from one maxillary tuberosity to the other. The gingival mucosa is elevated subperiosteally to expose the anterior maxilla up to the level of the infraorbital nerve. Once the piriform aperture is identified, the nasal mucosa is elevated from the nasal floor and nasal septum up to the level of the inferior nasal turbinates. The pterygomaxillary fissures on both sides must be exposed prior to the osteotomy. The intended Le Fort I osteotomy is marked on the maxilla with a sterile pen (Fig. 7). It is important to preregister the titanium miniplates and screws before performing the maxillotomy to ensure an exact fit when the maxilla is returned to its anatomic position at the time of closure. This technique reduces the risk of postoperative malocclusion.[8,33,37] The titanium miniplates and screws are secured over both sides of the intended Le Fort I osteotomy line. They are removed and carefully labeled for subsequent replacement at the time of closure.

Using an oscillating saw, bilateral Le Fort I osteotomies are made, staying above the roots of the teeth to avoid dental injury. Another osteotomy is made to separate the bony nasal septum from the hard palate. Using a curved osteotome, the maxillary tuberosities are disarticulated from the pterygomaxillary fissures bilaterally. The hard palate is then down-fractured and mobilized inferiorly into the oral cavity. The transoral retractor is readjusted to retract the down-fractured maxilla inferiorly. The tongue is carefully inspected to ensure that it is free from entrapment between the teeth. The remainder of the operation is similar to the transoral approach described earlier. At the time of closure, the maxilla is replaced and fastened with the preregistered titanium plates

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and screws. The gingival mucosa is reapproximated with interrupted 2-0 absorbable sutures.

Transmaxillary Palatal Split Approach (Extended Maxillotomy)

One major disadvantage of the Le Fort I maxillotomy is obstruction of inferior exposure by the down-fractured maxilla. This can be overcome by splitting the hard and soft palate and mobilizing the hemi-maxillae laterally (Figs. 7–9). Each hemi-maxilla maintains its own blood supply and innervation from its respective palatine artery and nerve. This modified approach is referred as the transmaxillary palatal split approach, or extended "open-door" maxillotomy, and is essentially a Le Fort I osteotomy enhanced with an additional split of the hard and soft palate.[8,33] This approach provides rostral exposure of the sphenoid sinus and upper and middle clivus while maintaining the inferior exposure provided by a standard transoral approach. This is particularly useful for extensive lesions that involve the sphenoid sinus and clivus down to the body of C2. The lateral limits of this exposure are the cavernous carotid arteries, the occipital condyles, and the lateral masses of the C1-C2 complex. The major disadvantages of this approach are extended operating time and the complexity of reconstruction and wound closure.[33]

A Le Fort I osteotomy is initially performed as described earlier. The mucosa over the hard palate is incised slightly off the midline, continuing posteriorly through the soft palate, staying on one side of the uvula. Using an oscillating saw, the hard palate is split in the midline starting between the front incisors. The osteotomy traverses around the anterior nasal spine and continues posteriorly in the sagittal plane. Each hemi-maxilla is

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rotated outward and retracted laterally into the cheek (Figs. 7 to 9). A midline incision is made in the posterior pharyngeal wall and the surgical resection continues as described previously.

At the time of closure, each hemi-maxilla is restored to its anatomic location and fastened with preregistered titanium plates and screws. The mucosa over the hard palate and the sublabial incisions are reapproximated with interrupted absorbable sutures. The soft palate is closed in three layers with interrupted absorbable sutures.

Transpalatal Approach

The transpalatal approach provides increased rostral exposure of the upper and middle clivus through a standard transoral approach by excising the hard palate. This approach is useful for tumors of the craniovertebral junction that extend superiorly beyond the plane of the hard palate. In contrast to the transmaxillary approaches described earlier, this approach has the advantage of minimal facial disassembly.[4,37]

To disarticulate the hard palate, exposure above and below the hard palate through the nasal floor and oral cavity, respectively, must be obtained. Initially, a sublabial incision is made and the gingival mucosa is elevated subperiosteally to expose the piriform aperture. The submucosal dissection is performed to expose the nasal floor and nasal septum, similar to a sublabial transsphenoidal approach. A midline incision is made through the mucosa of the inferior surface of the hard palate that continues through the soft palate staying on one side of the uvula. The mucosa is elevated subperiosteally to the alveolar margin around the greater palatine foramen, and the levator muscle is detached from the posterior margins of the hard palate. An oscillating saw is used to cut

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around the margin of the palate near the alveolar edge staying medial to the greater palatine foramen (Fig. 10). Through the sublabial exposure, the hard palate is disarticulated from the nasal septum and lateral nasal walls with an osteotome. The bony hard palate is removed from the oral cavity, thereby exposing the nasal septum, sphenoid sinus, and upper clivus (Fig. 10).[4,37]

The posterior pharynx is incised and tumor removal proceeds as described previously. At the time of closure, titanium microplates and screws are used to fasten the hard palate back to its anatomical position. Care should be taken not to place screws into the tooth roots. The soft tissues of the soft palate and palatal mucosa are reapproximated with interrupted absorbable sutures. The sublabial incision is also closed with interrupted absorbable sutures.

Transmandibular Approach (Median Labiomandibular Glossotomy)

The median labiomandibular glossotomy involves a lower lip and chin incision followed by midline split of the mandible and tongue. This approach was first described by Trotter[38] in 1929 and is used by otolaryngologists for resecting midline tumors located at the base of the tongue and the posterior pharynx.[39,40] It is also useful for accessing craniovertebral junction tumors and other lesions that extend inferiorly beyond C2 to about the C4 level if they are not accessible through a standard transoral approach.[9,21-23] We perform a tracheostomy before performing this extended approach.

A vertical curvilinear incision is made in the lower lip, starting in the midline and curving around the skin crease of the chin, then continuing inferiorly in the midline to the hyoid bone. The soft tissues and mucosa are elevated from the mandible laterally.

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Titanium plates and screws are contoured to the mandible and preregistered for later replacement. Using an oscillating saw, the mandible is split in the midline between the two lower incisors (Figs. 7 and 8). Removal of the teeth is not required in performing this osteotomy. The tongue is incised with monopolar cautery along the median raphe, a relatively avascular plane, posteriorly towards the median glossoepiglottic fold. Because the incision is in the midline, the innervation from the hypoglossal nerves to their respective halves of the tongue is preserved, as is the vascular supply to the tongue. The halves of the mandible and tongue are retracted laterally (Fig. 7 and 8). The floor of the mouth is split between the submaxillary ducts, and the incision is extended inferiorly to the level of the hyoid bone. The posterior pharyngeal wall is incised in the midline, exposing the middle-to-inferior clivus down to the C3 and C4 vertebral bodies. Tumor removal and closure proceeds as described earlier.

The mandible is restored to its anatomic position and reapproximated with preregistered titanium plates and screws. The tongue is reapproximated with interrupted absorbable sutures. The lip and skin incisions are reapproximated with 3-0 nylon sutures.

Conclusion

The transoral approach is effective in providing direct access to extradural midline lesions of the craniovertebral junction. Using a specialized retractor system, exposure can be obtained from the inferior clivus to the C2 body. Lesions that extend beyond the limits of exposure of a transoral approach can be accessed with extended approaches as described.

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Figure Legends

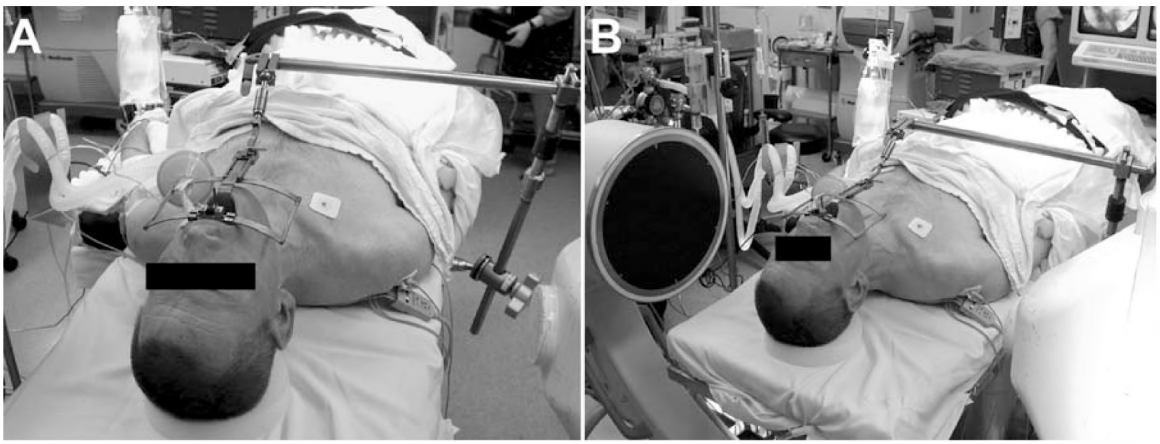

Figure 1. Operative positioning. A, The patient is placed in the supine position with the head resting on a doughnut pad. The neck is slightly extended to facilitate a direct line of sight to the craniovertebral junction. The patient is orally intubated. The Spetzler-Sonntag transoral retractor system is rigidly attached to the operating table with cross bars to prevent the retractor and the patient's head from moving intraoperatively. B, Intraoperative fluoroscopy is used throughout the operation.

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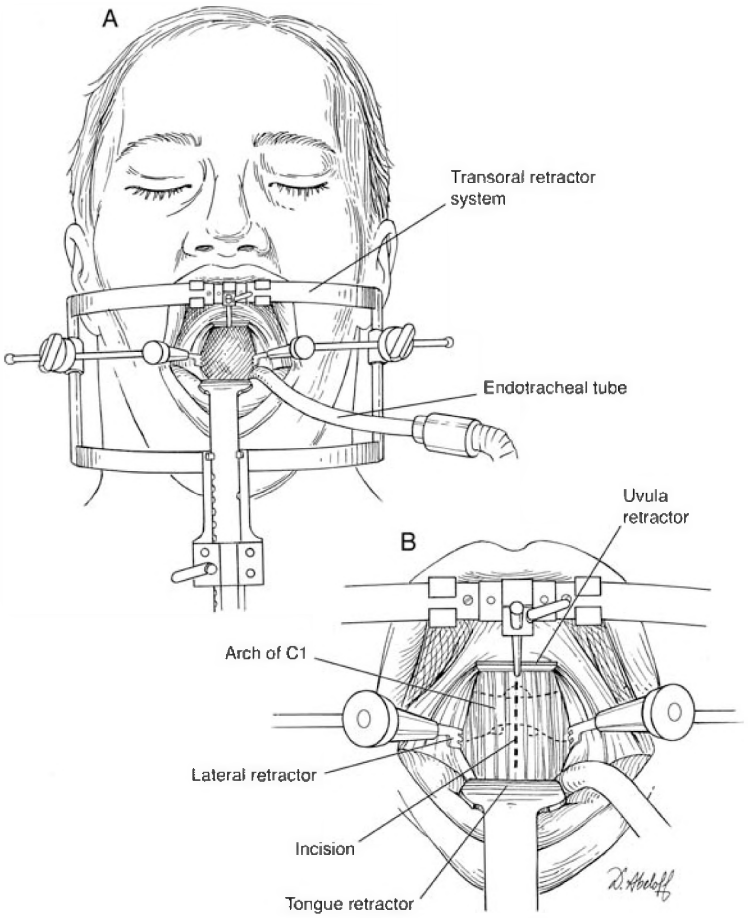

Figure 2. A, Illustration showing placement of the Spetzler-Sonntag transoral retractor system. The patient is orally intubated and the endotracheal tube exits the corner of the mouth. The retractor is held between the anterior teeth superiorly and the tongue inferiorly. B, Adjustable retractor blades are placed superiorly to elevate the soft palate and uvula and laterally from each side to maximize exposure of the posterior pharynx. The dotted line marks the posterior pharyngeal incision.

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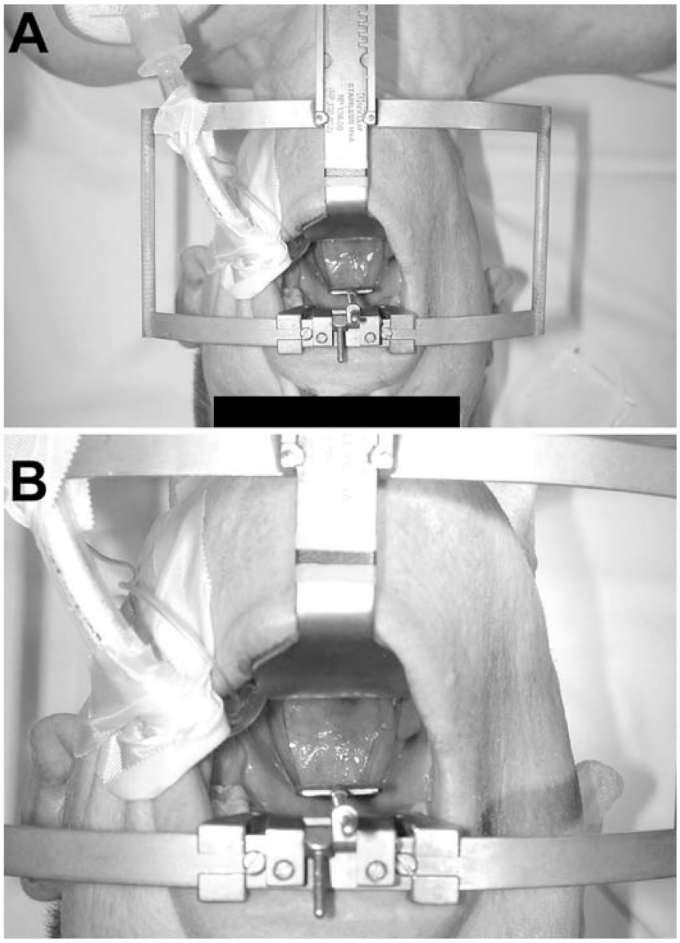

Figure 3. A, Intraoperative photograph (B, enlarged view) showing surgeon's view of the transoral exposure after placement of the Spetzler-Sonntag transoral retractor system. The surgeon operates from the head of the patient. The tongue is retracted inferiorly by a wide and rigid retractor blade. The endotracheal tube is routed along the side of the mouth to reduce tongue compression. It exits the corner of the patient's mouth and does not obstruct the surgical exposure. The soft palate and uvula are elevated superiorly with a small retractor blade that attaches to the transoral retractor. Teeth guards, which are attached to the retractor frame, anchor the frame on the superior teeth or, if the patient is edentulous, on the maxillary alveolar ridge, and protect the upper teeth.

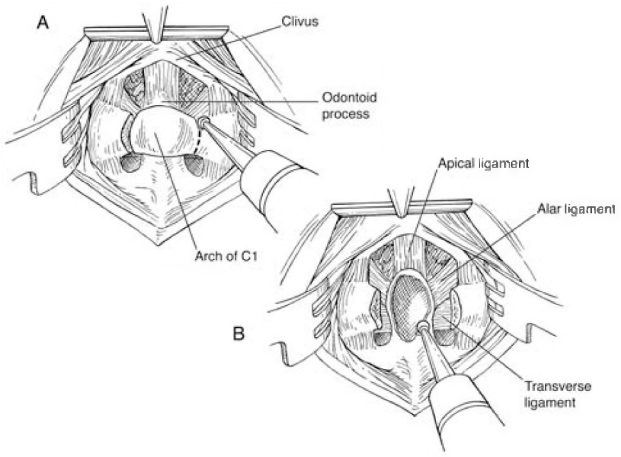

Figure 4. Removal of the arch of C1 and odontoid process. A, Bone cuts are made through the arch of C1 on both sides of the odontoid process using a high-speed drill, and the arch is subsequently removed with rongeurs. B, After the odontoid process is freed from its ligamentous attachments, the center of the odontoid is hollowed out with a high-speed drill, leaving an eggshell-thin layer of bone that is subsequently removed with Kerrison rongeurs or additional drilling.

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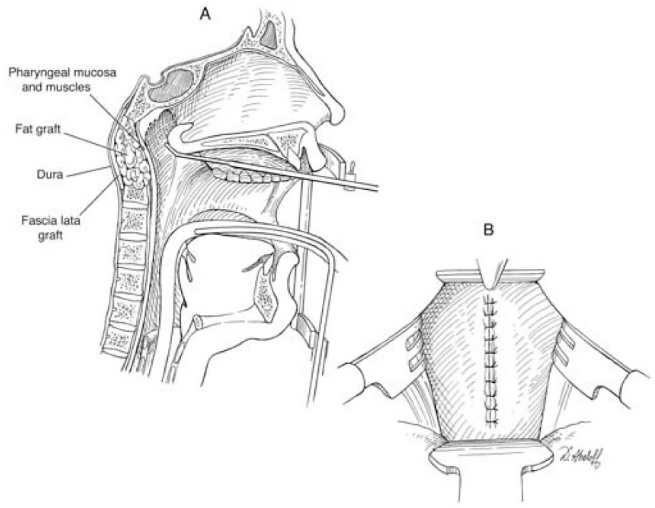

Figure 5. Closure technique. A, Defects in the dura mater are reconstructed with autologous fascia lata, fat, and fibrin glue. B, The pharyngeal muscles and mucosa are reapproximated in separate layers with interrupted absorbable sutures.

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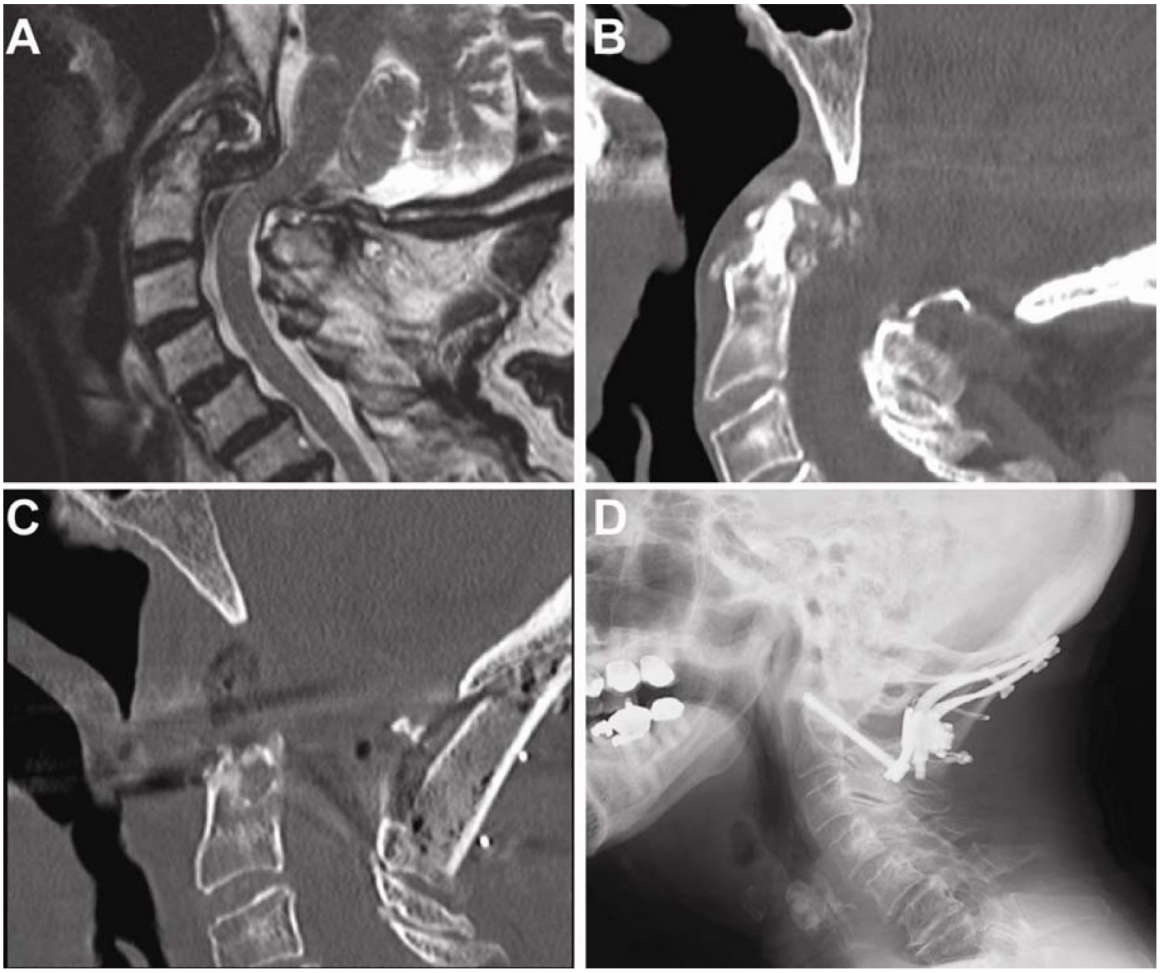

Figure 6. A, Preoperative T2-weighted sagittal MRI; B, preoperative sagittal CT. Both demonstrate severe ventral compression of the craniovertebral junction and posterior deviation of the spinal cord from a large degenerative pannus behind the odontoid process in a 81-year-old woman who presented with neck pain and early myelopathy. A transoral approach was performed to remove the large pannus at the craniovertebral junction followed by a posterior occipitocervical stabilization. C, Postoperative sagittal CT shows resection of the C1 arch, odontoid process, and pannus resulting in excellent decompression of the craniovertebral junction. D, Postoperative lateral cervical spine radiograph showing occipitocervical stabilization construct at 6 months after surgery.

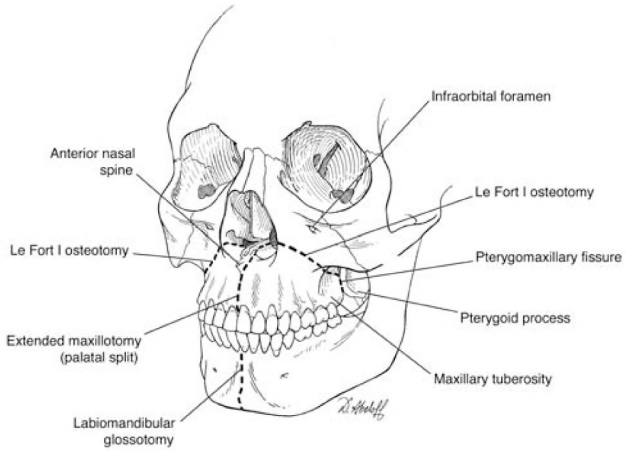

Figure 7. Illustration showing the locations of the osteotomies for extended transoral approaches.

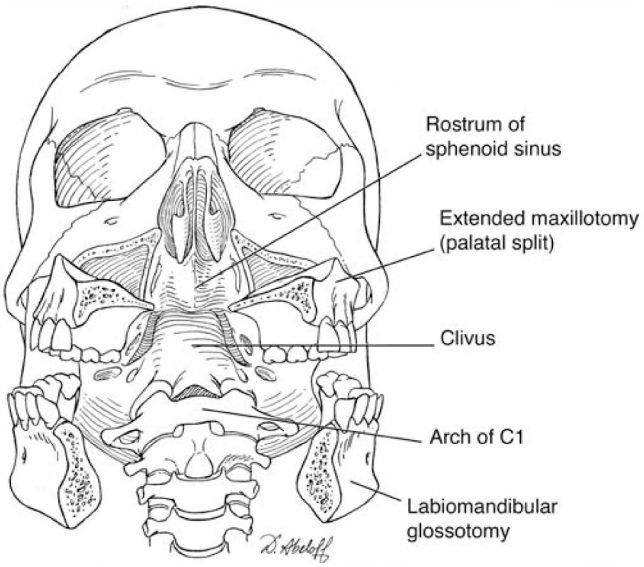

Figure 8. Illustration demonstrating the exposure gained by performing an extended transoral approach. The extended maxillotomy provides rostral exposure of the sphenoid sinus and upper clivus. The median labiomandibular glossotomy provides inferior exposure of the upper cervical spine down to C3 and C4.

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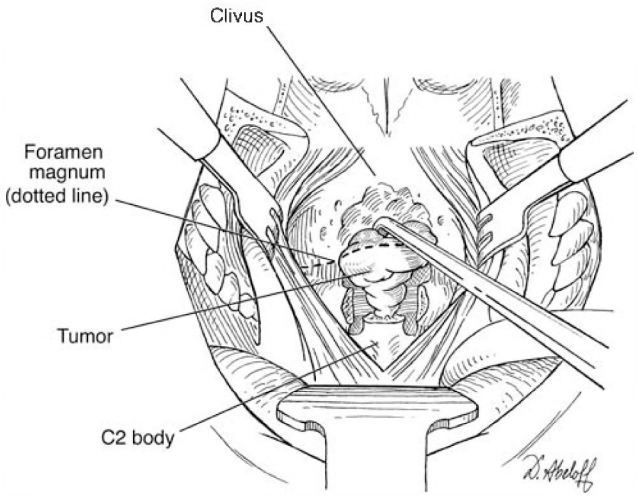

Figure 9. Illustration of surgical removal of a tumor involving the clivus, C1, and C2, using the transmaxillary palatal split approach (extended "open-door" maxillotomy).

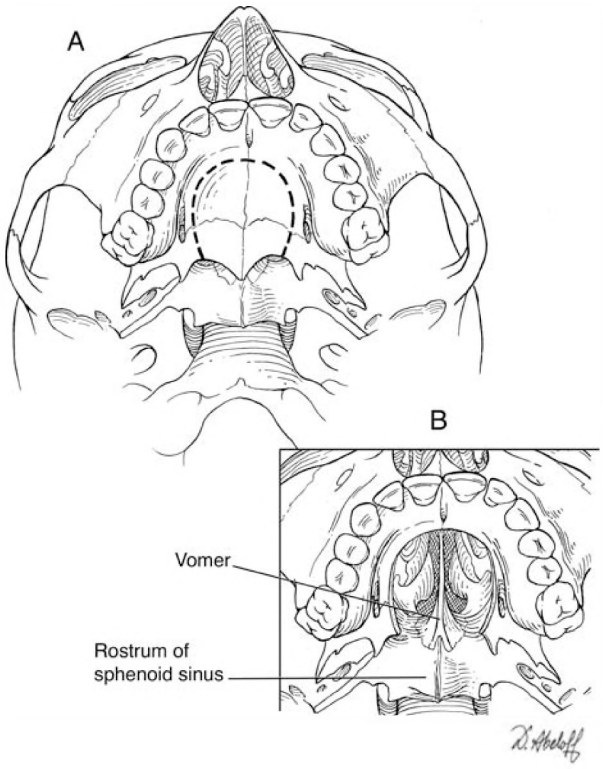

Figure 10. Illustration showing transpalatal approach. A, The dotted line marks the area of the hard palate to be removed. B, Removal of the hard palate exposes the sphenoid sinus and upper clivus.